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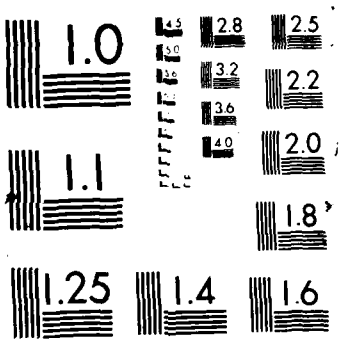
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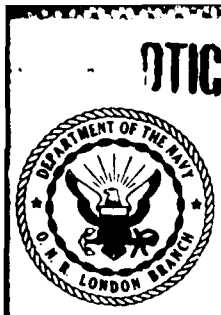
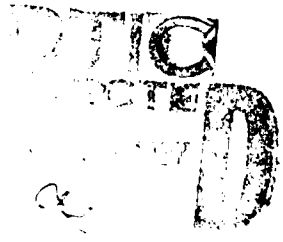


ONRL Report 7-028-R

Assessment of Electroceramics Research in Europe and the Middle East

Robert W. Vest

18 September 1987



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European/Middle Eastern research in microelectronics is discussed under four topic eas: dielectrics, sensors, hybrid microelectronics, and non-conventional processing.

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ASSESSMENT OF ELECTROCERAMICS RESEARCH IN EUROPE AND THE MIDDLE EAST

1 INTRODUCTION

The title of this report is a bit ambitious for someone who spent just 1 year, working part-time as a Liaison Scientist at the Office of Naval Research Branch Office, London--perhaps "some observations" would be more apropos than "assessment." Research in electronic ceramics is very extensive throughout Europe and the Middle East (E/ME), and much of it is of very high quality. I will try to give the flavor of this research based on my sample during the past year.

The most exciting thing that happened in electroceramics during my tenure in Europe was the report from IBM Zurich Laboratories of the discovery of high-transition-temperature superconducting ceramics. This initial discovery was followed up most rapidly by laboratories in the US and Japan, but now hundreds of laboratories in E/ME are actively involved or are planning to initiate research in the area. It is heartening that my replacement at ONRL will be Dr. Allen F. Clark (NBS, Denver), who will concentrate on superconducting materials.

Reviews of most of my liaison visits appeared in the European Science Notes (ESN) or as ONRL reports and I certainly do not intend to repeat that material in this report. Rather, I will touch on some of the highlights of those publications and discuss some of the things I learned from other liaison visits that for one reason or another did not result in publications. I will discuss research in four general areas: dielectrics, sensors, hybrid microelectronics, and nonconventional processing.

2 DIELECTRICS

Both basic and applied research activities on ferroelectric materials are widespread in E/ME, and some of this was discussed in my report on the meeting of the Dielectrics Society (*ESN* 41-9:494-496 [1987]). Professor G. Arlt (Aachen Technical University, West Germany) is continuing his pioneering work on the role of domain walls on properties of ferroelectric ceramics, and Professor Fontana (University of Metz, France) is doing some very interesting theoretical research to relate dielectric dispersion and lattice dynamics in relaxor ferroelectrics. A recently completed microstructure study at the University of Essex, UK, has identified nanoscale domains within normal macrodomains in relaxor ferroelectrics, thereby confirming earlier theoretical predictions of the existence of such domains. The relaxor ferroelectrics are being utilized in imaginative ways in pyroelectric detectors at Plessey Research, Caswell, UK (*ESN* 41-2:78-82 [1987]). The laser intensity modulation method developed by Professor Lang (Ben-Gurion University of the Nagev, Israel) is a potentially powerful experimental tool to study polarization distribution in ferroelectrics.

Research on electro-optic materials is also very active in E/ME, but the applied research in the industrial laboratories is being kept very proprietary. Some of the most interesting research I encountered was on use of the photorefractive effect for storing volume phase holograms. Professor Kratzig (University of Osnabruck, West Germany) is trying to identify the nature of the trapping centers in doped potassium tantalate-niobate (KTN) and to relate this to the figure of merit for holographic storage (ONRL Report 7-008-C). Professor Yacoby (Hebrew University, of Jerusalem, Israel) is also working with doped KTN, but is utilizing the dielectric-induced photorefractive effect, which he claims gives figures of merit 100 times larger in the same material (*ESN* 41-8:425-427 [1987]).

3 SENSORS

There is a great amount of interest in ceramic sensors in E/ME, and I had an opportunity to sample some of this work. The research at the University of Edinburgh, UK (*ESN* 41-4:193-197 [1987]) on integrated and hybrid pH sensors is top

quality, as is the research on semiconducting oxide gas sensors at AERE Harwell, UK (*ESN* 41-8:427-430 [1987]). The research on thick film pressure sensors for automotive applications at Marelli Autronica and the University of Modena, Italy (*ESN* 41-9:496-501 [1987] is the best I have seen in this area, and the research laboratory at Robert Bosch GmbH (West Germany) is involved in some very imaginative research on integrated pressure sensors using freely supporting structures created with thick film technology. All in all, I believe the ceramic sensor research in E/ME is as good as anywhere in the world.

4 HYBRID MICROELECTRONICS

Hybrid microelectronics in E/ME is undergoing changes and moving in directions very similar to its counterpart in the US and Japan. It is not that one part of the world is leading and the others following, but rather that all are responding to similar needs and challenges in their own ways. Looking at where the research is conducted one sees a very strong collaboration between the university and industrial research laboratories in Japan, in contrast to the US where the great majority of research is done in industrial laboratories. Europe falls somewhere between these two extremes. In Italy and particularly in Poland, the university-industrial interaction is especially strong, as detailed in two *ESN* articles (41-3:133-139 and 41-9:496-501 [both 1987]), but does not appear to be as prevalent elsewhere on the continent. In the past there was some excellent basic research in thick film components and materials at several universities in the UK (e.g., Imperial College, Chelsea College, and the University of Edinburgh), but this research has been either terminated or greatly reduced due to shifts in funding to other areas. Most of the university research in the UK is now centered in the polytechnics. For example, there is some good research being conducted at the Microelectronics [illegible] Middlesex Polytechnic in London with strong industrial support, and Kingston Polytechnic (Kingston-upon-Thames) is expanding their activities in hybrid microelectronics.

In the area of thick film ink suppliers, DuPont is the giant in E/ME as it is in the US, with about half of the market (precise sales figures of ink manufacturers are some of the most closely guarded secrets in the hybrid industry). DuPont manufactures thick film inks using intermediates manufactured in the US at Stevenage, UK, Besancon, France, and Neu-Isenburg, West Germany. The Stevenage facility was the subject of a recently published company profile (Cullen, 1987). The second largest supplier of thick film inks (approximately 25 percent of the market) is W.C. Heraeus GmbH with their production facilities in Hanau, West Germany. Heraeus has been considerably strengthened by their acquisition of Cermalloy in the US, as demonstrated by their facility in Byfleet, near London, which manufactures inks for the British market using intermediates from both West Germany and the US. The remaining 25 percent of the European thick film ink market is supplied by a number of smaller companies, most of them based in the US. For example, EMCA has a facility near Cambridge where they formulate inks for the European market using intermediates from their main plant in the US.

All of the commercial thick film suppliers in Europe carry out development projects, most commonly for products to satisfy a particular customers' needs, but only Heraeus conducts extensive research on the materials aspects of thick films. The rest of the companies, including DuPont, rely on their research laboratories in the US to conduct the more long range research studies. Two exceptions that I uncovered were in Yugoslavia (in process for *ESN* 41-10) and Poland (*ESN* 41-3:133-139 [1987]) where the lack of hard currency has forced them to undertake the materials research necessary to produce their own thick film inks.

There is an intense interest in surface mount technology (SMT) throughout Europe because of its potential for increasing reliability and reducing costs

through automated assembly. For example, see my reports on computer aided design for SMT in the UK (*ESN* 41-6:314-318 [1987]) and the European Microelectronics Conference (in process for *ESN* 41-11)). In 1986, SMT accounted for 10 percent of the European hybrid market, and a recent survey predicted that this will increase to 38 percent by 1990, so the trend is obvious. There is very little fundamental research going on in Europe (or in the US for that matter) on the materials aspects of SMT even though there are a number of areas where the depth of understanding is very poor (e.g., interface science). The best basic research seems to be in the area of heat transfer and thermal management.

There is some good long-range research underway in a number of European industrial laboratories on a variety of approaches to high-density interconnection systems. Several of these were discussed in my reports on the European Microelectronics Conference (in process) and Standard Telecommunications Laboratories (*ESN* 41-10:593-594 [1987]). Copper thick film technology is somewhat of an enigma in Europe. There is a significant use of copper thick films (e.g., six companies had displays of copper-based circuits at Hybrid Microtech '87, a seminar and trade show held in January, near London), and there is a lot of research in progress. However, very few of the people involved in the research are willing to talk about what they are doing, in contrast to the US where many technical papers are published and there is at least one conference per year dedicated to copper technology. The Europeans consider this area much more proprietary than does US industry.

5 NON-CONVENTIONAL PROCESSING

There are a number of research laboratories in E/ME involved in studies of alternate processing methods for electronic ceramics. I did not detect the level of interest in this area that exists in the US, but some good research is underway.

The Schott Glass Works in West Germany is a world leader in sol-gel processing, currently producing millions of square meters per year of oxide films on glass by the dip coating process. Their research laboratories are currently working on films with tailored optoelectronic, magnetic, and electrochromic properties. Professor Livage (University of Pierre and Maria Curie, France) is doing some excellent basic research on hydrolysis-condensation reactions but the most exciting area, at least to me, is his research on all-gel devices. These devices utilize the electronic properties arising from hopping of unpaired electrons between metal ions in different valence states, the ionic properties arising from proton diffusion through the liquid phase, and the electrochemical processes which involve both phases. These two research projects are discussed in ONRL Report 7-005-C.

Basic research on precursor compounds for metal organic chemical vapor deposition (MOCVD) is underway at a number of chemistry departments in the UK (e.g., Oxford University, University of Reading, and Queen Mary's College), and I ran across some imaginative reactor design for MOCVD deposition of ferroelectric and conducting oxide films at Imperial College in the UK (*ESN* 41-[illegible]555 [1987]). Also at Imperial College the research on solid oxide fuel cells is almost totally dependent on the development of innovative processing techniques to build the multichannel honeycomb or corrugated reactor structures, and to apply the air and fuel electrodes to these structures.

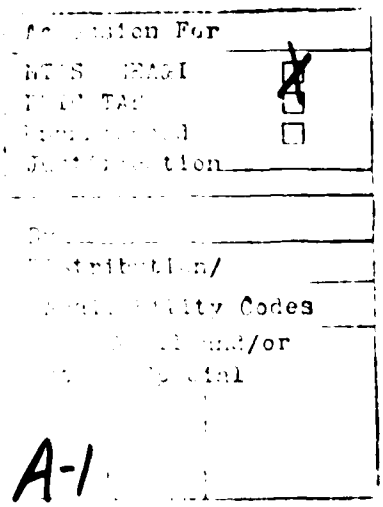
6 SUMMARY

Some excellent [illegible] in France, West Germany, Italy, and [illegible] are very active in research on electronic ceramics, and I was somewhat surprised at the high quality of research of several laboratories I visited in [illegible] Yugoslavia. The UK, which [illegible] than its share of innovative research in the past, is suffering to [illegible] cause of budget cuts to the universities

but some excellent research is being carried out in the industrial laboratories. Although there is some very good research on electronic ceramics in E/ME, I would rate the overall quality and quantity on a level slightly below that of the US and Japan. Unfortunately, I only had time to visit laboratories in less than half the countries in E/ME so my assessment may suffer from sampling error.

7 REFERENCE

L. Cullen, "DuPont Electronic Materials Division, Stevenage, England," *Hybrid Circuits*, 13 (May 1987), 89-92.



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